# Analysis of a Magnetic Release in a Molded Case Circuit Breaker

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**Abstract — In order to optimize the magnetic release in a molded case circuit breaker, it is necessary to calculate the magnetic force of the magnetic release with the short calculating time. Generally the three-dimensional (3D) finite element method (FEM) is used to analyze the magnetic release, because the structure of the magnetic release is complex. However it takes long time to obtain the magnetic force of the magnetic release by using the 3D FEM. In this paper, we propose the advanced two-dimensional (2D) analysis method for the magnetic release which can replace the 3D FEM in order to reduce the calculating time. In the advanced 2D analysis method, an original 3D model of the magnetic release is transformed into a simplified 2D model composed of several segments, and the simplified 2D model is analyzed by the 2D FEM. The calculating time of this method is much shorter than that of the 3D FEM. And this method is validated by experimental results.**

## I. INTRODUCTION

Molded case circuit breakers (MCCBs) are widely used in low voltage power distribution systems due to compactness, long lifetime, and minimal maintenance. When the short circuit current flows into the MCCB, a magnetic release trips the mechanism of the MCCB, and the MCCB interrupts the short circuit current. The magnetic release is an important unit in the MCCB [1]-[3]. Therefore it is necessary to optimize the magnetic release in order to improve the interrupting performance of the MCCB [4].

Recently, there was a study on the dynamic characteristics of the magnetic release in the MCCB with three-dimensional (3D) finite element method (FEM) [5]. However, with the 3D FEM, it takes much time to calculate the magnetic force, and it is difficult to optimize the magnetic release.

In this paper, we present the advanced two-dimensional (2D) analysis method of the magnetic release in the MCCB with short calculating time. An original 3D model of the magnetic release is transformed into a simplified 2D model composed of several segments, and it is analyzed by the 2D FEM. This method reduces the calculating time to obtain the magnetic force of the magnetic release. In order to verify the validity of the proposed method, the calculated results were compared with the experimental results.

## II. ANALYSIS METHOD

Fig. 1 shows the typical structure of the magnetic release in the MCCB. It basically consists of a move core, a fix core, a bimetal, and a conductor. The move core, the fix core, and the bimetal are ferromagnetic bodies. The move core is able to rotate upon an axis by the magnetic force, and trips the mechanism of the MCCB. The fix core is the

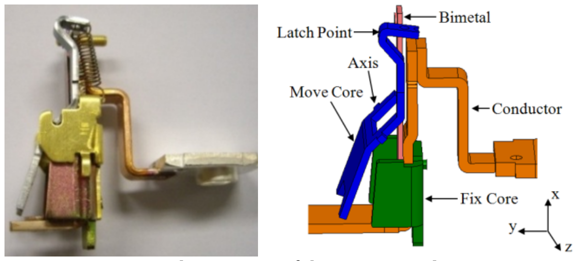



Fig. 1. The structure of the magnetic release

magnetic path in which magnetic flux well flows and helps increase the magnetic force of the move core. The bimetal is a tripping unit for the over current, and the conductor is the path of the current. The latch point is the contact point which pushes the latch of the mechanism in the MCCB and trips it.

The governing differential equation to analyze the magnetic force of the magnetic release is formulated as follows

$$\nabla \times \nu(\nabla \times \boldsymbol{A}) = \boldsymbol{J_0}\,, \tag{1}$$

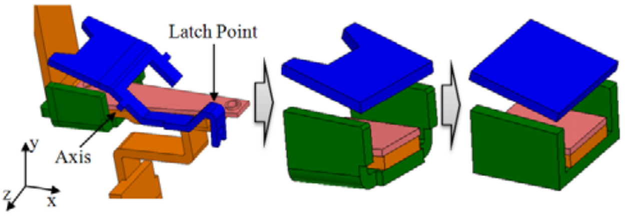
where $\boldsymbol{A}$ is the vector magnetic potential, $\boldsymbol{J_0}$ is the external current density, and $\nu$ is the reluctivity which is defined as $\nu = (\mu_0 + \mu_0\chi_m)^{-1}$. The vector magnetic potential is obtained from (1), and used to calculate the magnetic force as follows

$$F_{mag} = \iint \left(\frac{1}{\mu_0}(\boldsymbol{B}\cdot\boldsymbol{n})\boldsymbol{B} - \frac{1}{2\mu_0}\boldsymbol{B}^2\boldsymbol{n}\right) dS\,, \tag{2}$$

where $F_{mag}$ is the magnetic force, $\boldsymbol{n}$ is the unit vector of the normal direction along the surface, and $S$ is the area of the outer surface around the move core.

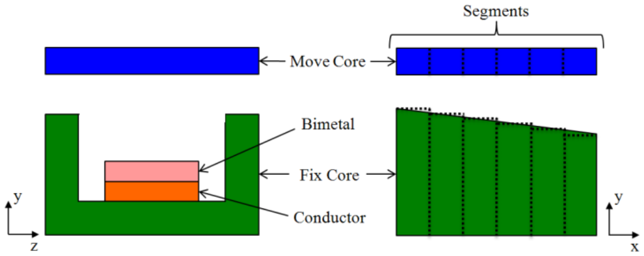
Fig. 2 shows the simplification process of the magnetic release for the advanced 2D analysis method. Considering the magnetic property and the operation principle of the magnetic release, we transform an original 3D model into a simplified model in order to reduce the calculating time. The simplified model is divided into several small segments as shown in Fig. 3, and the magnetic force of the each segment is individually calculated by the 2D FEM. The torque and the total magnetic force acting on the move core are obtained by summating all magnetic force in segments taking into account the axis of the magnetic release.

Table I shows the comparison between the advanced 2D analysis and the conventional 3D analysis, when the 3000A peak current flows through the conductor of the magnetic release. The 3D analysis is carried out by Maxwell 3D version 13. The torque and the magnetic force acting on the latch point obtained by the advanced 2D analysis are similar to the results of the conventional 3D analysis. However the calculating time of the advanced 2D analysis is much shorter than that of the conventional 3D analysis.




(a) Original model (b) Semi-simple model (c) Simple model

Fig. 2. The simplification process of the analysis model




(a) Front view (b) Side view

Fig. 3. The transformation to the 2D analysis model

TABLE I
COMPARISON BETWEEN ADVANCED 2D ANALYSIS AND CONVENTIONAL 3D ANALYSIS

| | Advanced 2D Analysis | Conventional 3D Analysis |
|---|---|---|
| Torque [Nm] | 0.0864 (105.4 %) | 0.0820 (100.0 %) |
| Magnetic Force [N] | 5.08 (105.4 %) | 4.82 (100.0 %) |
| Calculating Time [min.] | 0.5 (2.5 %) | 20 (100.0 %) |
| Number of elements | 3784 | 83289 |
| Specification of Calculating Computer | 3.8GHz Dual CPU | |
| | 2GB RAM | |

## III. EXPERIMENT RESULTS

Fig. 4 shows the experimental equipment for measuring the magnetic force acting on the latch point of the magnetic release in the 250AF MCCB. The quartz force sensor is used to measure the magnetic force of the magnetic release, when the current flows through the conductor. In order to record the whole of the magnetic force of the magnetic release, the force sensor prevents the move core from moving. Fig. 5 shows the experimental waveforms of the current and the magnetic force. When 500A peak current flows through the MCCB, the peak magnetic force acting on the latch point is 0.53N.

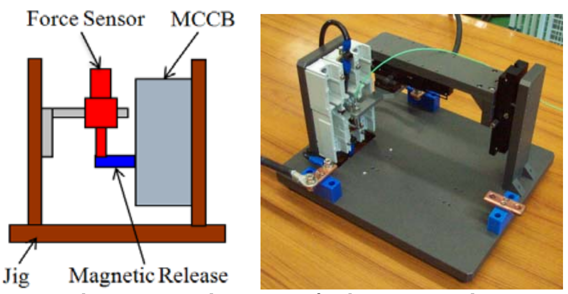



Fig. 4. The experimental equipment for the magnetic release

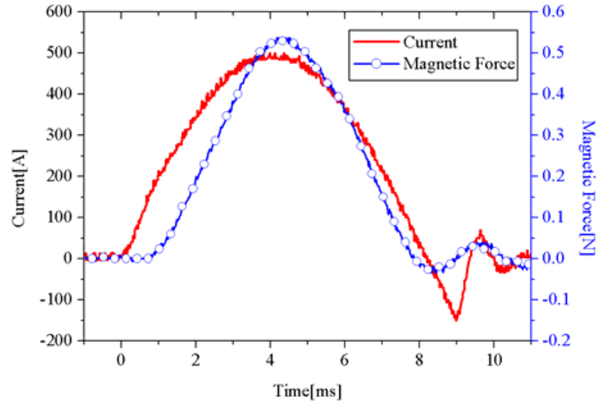



Fig. 5. The experimental waveforms of the current and the magnetic force

TABLE II
COMPARISON BETWEEN ADVANCED 2D ANALYSIS AND EXPERIMENT

| Current [A] | Magnetic Force [N] | | Error [%] |
|---|---|---|---|
| | Advanced 2D Analysis | Experiment | |
| 2000 | 3.32 | 3.50 | 5.2 |
| 2500 | 4.24 | 4.30 | 1.5 |
| 3000 | 5.08 | 4.70 | 8.1 |

Table II shows the results of the advanced 2D analysis method and the experiment. To verify the validity of the advanced 2D analysis method, the magnetic force acting on the latch point of the magnetic release is calculated under different currents. The calculated results have a good match with the experimental results. It means that the advanced 2D analysis method is reasonable and effective to calculate the magnetic force of the magnetic release.

## IV. CONCLUSION

In this paper, we present the advanced 2D analysis method of the magnetic release in the MCCB. This method is based on the simplified 2D model which can be analyzed by 2D FEM. With this method, we can reduce the calculating time, and obtain the reliable value of magnetic force of the magnetic release.

## V. REFERENCES

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